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Abundance and spatial distribution of mosquitoes across three ecological zones of Ondo State Nigeria

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Abstract
The study was undertaken in three ecological zones of Ondo State to determine the abundance and spatial distribution of mosquitoes in the ecological zones of the state. Twenty (20) sampling sites randomly distributed across each of the zones were sampled using aspirators, dippers and pipettes. The results revealed 12 mosquitoes species belonging to 3 genera, these include 5 species of *Culex (Cx. quinquefasciatus, Cx. andersoni, Cx. duttoni, Cx. pipiens* and *Cx. trigripis),* 4 *species of Aedes (Ae. aegypti, Ae. albopictus, Ae. vittatus* and *Ae. palpalis)* and 3 *species of Anopheles (An. gambiae, An. arabiensis and An. funestus).* The study further showed that *Cx. quinquefasciatus* was the most predominant *Culex* species observed in Idanre and Ese Odo, while *Cx. andersoni* was the predominant *Culex* species in Ondo, Ifon and Ikare Akoko. *Ae. aegypti* was the most dominant in all the locations except Ese Odo. *An. gambiae* has the highest occurrence in all the ecological zones. The results of this study show that the area is rich in mosquitoes, and the abundance of the mosquitoes especially the *An. gambiae* is of public health importance.

Keywords: Mosquitoes, Abundance, Physico-chemical parameters, Ecological zones

1. Introduction
Mosquitoes are notorious insects which transmit many dreadful diseases causing critical health challenges to human. Diseases vectored by mosquitoes include: malaria, filariasis and yellow fever [1]. These diseases cause high morbidity and mortality in human. Despite progress made to combat malaria and mosquito related diseases, globally, about 3.2 million people are still at risk of malaria. In Nigeria, malaria still remains one of the leading causes of childhood and maternal morbidity and mortality, low productivity and reduced school attendance [2]. Nigeria was ranked as the highest country with malaria prevalence on the world malaria day in 2015 due to about 300,000 deaths which usually occur each year as a result of malaria [3].
Climatic factors such as temperature, rainfall and relative humidity are vital components of the ecosystem that regulate the population density of mosquitoes [4]. Temperature influences vector development rates, mortality and behaviour. Temperature can also interact with rainfall to regulate evaporation thereby affecting the availability of water habitats. Rainfall, temperature and humidity indirectly influence land cover and land use which can promote or disrupt vector populations. Climate change is one of the most important factors to be considered in vector ecology because it affects human health. The link between climate and diseases with various modes of transmission has been identified with the strongest association being between climate and mosquito-borne diseases [5]. Dengue fever has been associated with vegetation indices, tree cover, surrounding land cover and housing quality [6]. Transmission is associated with changes in temperature, rainfall, humidity as well as level of immunity. The IPCC Special Report on Regional Impacts of Climate Change [7] acknowledged that climate has an impact on vector-borne diseases. Changes in climate affect potential geographical distribution and transmission of vector-borne infectious diseases such as malaria. There are many substantial research challenges associated with studying linkages among climate, ecosystems, and infectious diseases. For instance, climate-related, such as rapid evolution of drug- and pesticide-resistant pathogens, swift global dissemination of microbes and vectors

through expanding transportation networks, and deterioration of public health programs in some regions. Proper understanding of the environmental factors that promote the breeding of mosquitoes becomes imperative for successful planning of mosquito control measures [8]. The study aim is to identify the predominant mosquito species in each ecological zone and show how the ecological vegetation and physicochemical parameters influence the abundant of mosquitoes in the study area.

2. Materials and methods

2.1 Study area

This study was carried out in Ondo State, which is one of the States in the Western State of Nigeria. The State comprises of three ecological zones: mangrove forest, rainforest and savannah forest. The locations sampled are Idanre, Ondo, Ifon, Ikare-Akoko and Ese-Odo. The tropical rainforest used was located in Idanre (Latitude of 7º 10' 38.60″ and a Longitude 5º 09' 00.1″), Ifon in Ose (Latitude of 6º 55' 00.70″ and a Longitude of 5º 45' 4.70″), Ondo East Local Government Area (Longitude 5º 03' 82'' E and Latitude 7º 27' 84'' N) with a mean annual rainfall of about 4000 mm and temperature range from about 20.6 ºC to 33.5 ºC. The derived savannah is chosen from Akoko North East Local Government Area (Ikare-Akoko) of Ondo State Nigeria. It is located between longitude (5º 77' 80'' E and latitude 7º 65'96'' N). The mean annual rainfall is about 3500mm and temperature ranges from 26 ºC to 39 ºC. Ese-Odo Local Government Area of Ondo State is a mangrove forest. It is on (Latitude 7º 21'14'' N and longitude 5º 02' 25''E). The climatic condition of the area is cold with sea breeze and it experiences a mean annual rainfall of about 400 mm to 450 mm which occurs normally between April to September and has its dry season from November to March. It has mean annual temperature of 28 ºC.

2.2 Sampling, collection and identification of mosquito larvae

Twenty (20) sampling sites randomly distributed across each of the zones were sampled using aspirators, dippers and pipettes from January 2015 to December 2016. The habitats sampled were: abandoned plastics, gutters, tanks, puddles, tree holes and used tyres. A hand dipper which is a white plastic cup with a volume of 350 ml attached to a handle was used to sample the mosquito population and the samples were concentrated through a small mesh screen using a concentrator cup. The samples were then preserved with 70% ethanol in plastic snap-cap vials with a volumetric capacity of ~ 55 ml and transported to the laboratory for identification. The larvae were identified to species level using dissecting microscope and guided by the morphological keys [9, 10, 11].

2.3 Determination of the physico-chemical parameters

The water sample where the larvae were harvested was analyzed for physicochemical parameters on the field. The parameters include temperature, pH, relative humidity, dissolved oxygen and electrical conductivity. Model 350 pH meter (350 201) which is a portable battery operated meter was used to measure the pH, electrical conductivity of the water samples was measured using a portable battery operated conductivity meter (Model 470), dissolved Oxygen (DO_2) was measured using pre-calibrated dissolved oxygen meter (Model 970) and portable thermo-hygrometer was used in measuring the temperature of all water samples and also the relative humidity of the environment.

All data collected were analyzed using one way analysis of variance (ANOVA) and where there were significant differences, Tukey test at $p<0.05$ was used to separate the means using SPSS 20.0.

3. Results

3.1 Mosquito larval habitats and physico-chemical parameters of the sampled water in the ecological zones of Ondo State.

Table 1 shows the types of mosquito larva collected per habitat in the three ecological zones in Ondo State. The habitats in which mosquito breeding was found include abandoned plastics, puddles, gutters, tyres, tanks and tree holes. Puddles made up the largest breeding site (22.24%) while tree holes made up lowest breeding site (6.68%). Puddles (176), gutters (165) and tree holes (87) were most abundant in Ese-odo (mangrove forest) while abandoned plastics (166), tyres (140) and tanks (163) were most abundant in Ondo, Ikare-Akoko and Idanre respectively.

From the result in Table 2, it was observed that temperature, relative humidity, pH, electrical conductivity and dissolved oxygen are the major factors that could play an important role in breeding and propagation of mosquitoes. Table 2 shows the result of the physicochemical parameters conducted on the water where the mosquito larvae were collected. The result shows that dissolved oxygen (ppm/mgl) of the water from Idanre (2.06±0.02ppm/mgl) was not significantly different from that of Ifon (2.06±0.02ppm/mgl) but the dissolved oxygen from Idanre and Ifon were significantly different from those collected from Ondo (1.95±0.12ppm/mgl), Ikare-Akoko (2.36±0.01ppm/mgl) and Ese-odo (2.67±0.12ppm/mgl) respectively ($P<0.05$). The highest dissolved oxygen (2.67±0.12ppm/mgl) in the ecological zones was obtained in Ese-odo; a mangrove forest in Ondo State. Meanwhile, the least dissolved oxygen (1.95±0.12ppm/mgl) was obtained in Ondo; a rainforest area of Ondo State. Similarly, the highest electrical conductivity (209.33±2.42 µs/cm) in the study area was observed in Ikare-Akoko; a derived savannah while the least electrical conductivity (92.03 ±0.24µs/cm) was observed in Ese-odo; a mangrove forest. It was further observed that the electrical conductivity of Ese-odo was not significantly different from that of Ondo (96.49 ±0.23µs/cm). Table 2 also shows that the breeding temperature varies from one ecological zone to another. For instance, highest temperature (27.22 ± 0.53 ºC) of the breeding water was observed in Idanre; a rainforest while the least breeding temperature (25.09 ± 0.03 ºC) was noted in Ese-odo; a mangrove forest. The breeding temperature in Ikare-Akoko (26.25 ± 0.07 ºC)); a derived forest was significantly different from that of rainforest and mangrove forest ($P<0.05$). It was also observed in the study that the relative humidity where mosquito breeding was observed were not significantly different ($P>0.05$) from rainforest (Idanre, Ondo and Ifon) to derived savannah (Ikare-Akoko) but the relative humidity of the mangrove forest (Ese-odo) where the highest relative humidity (76%) was recorded was significantly different from other ecological zones ($P<0.05$). It was further observed from Table 2 that the pH of breeding water in Idanre (7.15) was not significantly different from that of Ondo (7.13± 0.00). Also,

that of Ifon (7.07 ± 0.00) and Ikare-Akoko (7.07 ± 0.02) were not significantly different from each other (P>0.05). The physicochemical range where mosquito breeding was observed in the ecological zone include dissolved oxygen range of 1.95 ± 0.12 – 2.67 ± 0.12ppm/mgl, electrical conductivity range of 92.03 ± 0.24 -209.33 ± 2.42µs/cm, temperature range of 25.09 ± 0.03 – 27.22 ± 0.53 ºC, relative humidity range of 62.67 ±1.15 -76.00 ± 1.12% and pH range of 7.07 ± 0.00 -7.24 ± 0.00.

Table 1: Total number of mosquito larvae obtained at different breeding sites.

Locations	Abandoned Plastics	Puddles	Gutters	Tyres	Tanks	Tree holes
Idanre	133	114	115	88	163	41
Ondo	166	133	91	101	52	30
Ifon	143	125	123	113	73	36
Ikare-Akoko	95	131	83	140	54	37
Ese-odo	61	176	165	118	93	87
Total	598	679	577	560	435	204
Percentage (%)	19.59	22.24	18.90	18.34	14.25	6.68

Table 2: Physico-chemical parameters of the mosquito breeding water in different ecological zones of Ondo State.

Locations	DO	EC	TEMP	RH	pH
Idanre	2.06±0.02^{b}	144.67±3.18^{c}	27.22±0.53^{d}	62.67±1.15^{a}	7.15±0.01^{b}
Ondo	1.95±0.12^{a}	96.49±0.23^{a}	26.96±0.01^{c}	63.67±0.87^{ab}	7.13±0.00^{b}
Ifon	2.06±0.02^{b}	107.26±0.79^{b}	26.97±0.02^{c}	66.67±1.05^{b}	7.07±0.00^{a}
Ikare	2.36±0.01^{c}	209.33±2.42^{d}	26.25±0.07^{b}	62.67±1.25^{a}	7.07±0.02^{a}
Ese-odo	2.67±0.12^{e}	92.03±0.24^{a}	25.09±0.03^{a}	76.00±1.12^{c}	7.24±0.00^{c}

Mean followed by the same letter along the column are not significantly different using (p>0.05) Tukey's Test.
KEYS: DO – Dissolve Oxygen (ppm/mgl); EC – Electrical Conductivity (µs/cm);
Temp – Temperature (ºC); RH – Relative humidity (%).

3.2 Abundance and distribution of mosquito larvae in the ecological zones of Ondo State

The results in Table 3-5 showed that most of the species and number of larvae collected across the zones were significantly different (P<0.05). *Cx. quinquefasciatus* was the most abundant species in Ese-odo (50.67±2.03) while *Cx. quinquefasciatus* and *Cx. andersoni* were the most abundant in Idanre, Ondo, Ifon and Ikare-Akoko respectively (Table 3). The least abundant mosquito species were *Cx. tigripis* (4.00±4.00) in Idanre and Ikare-Akoko (20.00±5.03) while the species was completely absent in Ifon and Ese-odo. Similarly, *Cx pipiens* was not encountered in Ondo and Ifon. *Cx. quinquefasciatus*, *Cx. andersoni* and *Cx. duttoni* were evenly distributed in all the three ecological zones as these species were encountered in the three ecological zones while *Cx. trigripis* was not encountered in Ifon and Ese-odo, and *Cx. pipiens* was completely absent in Ondo and Ifon (Table 3).

Table 4 shows the abundance and distribution of *Aedes* spp across the ecological zones. Four species of *Aedes* were identified from the study area, these include *Ae. aegypti*, *Ae. albopictus*, *Ae. vittatus and Ae. palpalis*. All these species with the exception of *Ae. palpalis* were observed in all the ecological zones. But *Ae. palpalis* was absent in Idanre and Ondo. It was also noted that the abundance of *Ae. aegypti*, *Ae. albopictus* and *Ae. vittatus* were not significantly different in the freshwater ecological zones (Idanre, Ondo and Ifon) while the abundance of *Ae. aegypti* (68.33±8.09) in Ikare-Akoko (derived savannah) was significantly different from other *Aedes* spp from the same location (Table 4).

In Table 5, three species of genus *Anophelinae* were observed: *An. gambiae*, *An. arabiensis* and *An. funestus*. But the abundance of *An. gambiae* was the highest in all the ecological zones. Notably, *An. arabiensis* was absent in Ifon, Ikare-Akoko and Ese-odo, and *An. funestus* was not encountered in Idanre and Ondo which are freshwater ecological zones. In general, *An. gambiae*, a notable malaria mosquito in Nigeria was the most abundant species of mosquitoes in all the ecological zones. This species was also evenly distributed across the three ecological zones studied in this research.

Table 3: Abundance and distribution of *Culex* mosquitoes in ecological zones of Ondo State.

Species distribution	Idanre	Ondo	Ifon	Ikare-akoko	Ese-odo
Culex quinquefasciatus	69.33±9.96^{c}	2.33±8.41^{b}	42.33±8.65^{bc}	43.33±4.91^{b}	50.67±2.03^{e}
Culex anderson	59.33±7.51^{bc}	56.67±8.29^{b}	59.00±10.44^{c}	61.67±9.94^{b}	32.00±2.31^{c}
Culex duttoni	21.67±1.45^{a}	36.67±5.78 ^{b}	23.33±4.49^{b}	20.00±5.03^{a}	13.67±1.45^{b}
Culex tigripis	4.00±4.000^{a}	6.00±6.00^{a}	0.00±0.000^{a}	20.00±5.03^{a}	0.00±0.000^{a}
Culex pipiens	8.00±5.29^{a}	0.00±0.000^{a}	0.00±0.000^{a}	44.00±4.62^{b}	42.00±4.36^{d}

Mean followed by the same letter along the column are not significantly different using (p>0.05) Tukey's Test

Table 4: Abundance and distribution of *Aedes* mosquitoes in ecological zones of Ondo State.

Species distribution	Idanre	Ondo	Ifon	Ikare-akoko	Ese-odo
Aedes aegypti	56.67±8.67[b]	51.33±12.24[b]	59.33±10.53[b]	68.33±8.09[c]	43.00±9.71[ab]
Aedes albopictus	52.67±5.70[b]	43.67±10.11[b]	55.33±9.77[b]	24.67±5.46[ab]	82.33±22.06[b]
Aedes vittatus	46.00±6.43[b]	40.67±8.97[b]	49.67±8.41[b]	37.67±8.84[b]	47.67±3.84[ab]
Aedes palpalis	0.00±0.000[a]	0.00±0.000[a]	13.33±2.60[a]	13.33±2.60[a]	31.67±4.10[a]

Table 5: Abundance of *Anopheles* mosquitoes in ecological zones of Ondo State.

Species distribution	Idanre	Ondo	Ifon	Ikare-akoko	Ese-odo
Anopheles gambiae	83.00±4.93c	89.33±9.62a	82.67±21.86b	87.00±19.52b	82.67±21.86b
Anopheles arabiensis	36.00±6.11b	51.33±12.24b	0.00±0.000a	0.00±0.000a	0.00±0.000a
Anopheles funestus	0.00±0.000a	0.00±0.000a	23.67±4.26a	18.00±3.00a	31.67±12.09a

4. Discussion

The study area was rich in mosquitoes, mosquitoes breed virtually in all habitats sampled which were ground pools, domestic containers, tanks, tyres, tree holes, gutters and manmade containers which were the main breeding sites for mosquitoes. These breeding sites are common in the study area as a result of human activities, poor economic conditions; low literacy levels, poor sanitation level and indiscriminate disposal of discarded household materials which results in abundance of pools, ponds, puddles, water collections in tins, bowls, drums, clay pots and tree holes. Drums, clay pots and bucket containers of various sizes are used for domestic water collection during raining season. These water containers are sited around human dwellings where adult female mosquitoes can oviposit and subsequently breed its pre-adult stages (larvae and pupae).

The physico-chemical parameters of these breeding habitats were noted to be favorable for mosquito breeding. The dissolve oxygen (DO_2) of the water collected from the rainforest was between the range of (1.95-2.06 ppm/mgl) while that of Ikare-Akoko was 2.36 ppm/mgl and that of Ese-odo is 2.67 ppm/mgl. Generally, the DO_2 of the studied areas was low (1.95 – 2.67). This might be because of the discharge of agricultural wastes, domestic wastes and organic material into water body. The survival of larvae when submerged depends on their ability to absorb oxygen through the cuticle. When the level of DO_2 is low the rate of loss of buoyancy is said to be rapid, this suggests that the outward diffusion of gas into the water is significant. This might be the reason why there is abundance of *Cx. quinquefasciatus* when the DO_2 was low because it has the ability to survive for considerable longer period than any other species. The electrical conductivity of the water sampled in Idanre, Ondo and Ifon were close to each other but Ikare-Akoko has the highest electrical conductivity (209 µs/cm) while Ese-odo has the lowest (92 µs/cm). Ese-odo has the highest relative humidity of 76% while Ikare-Akoko and Idanre has a relative humidity of 62%, Ifon was 66% and Ondo was 63.% The pH recorded in the studied area were slightly alkaline (7.07-7.24) and this might have resulted in the abundance of mosquitoes in the studied areas. This is because most mosquito species thrive better in alkaline environment. Similar result has been reported by Afolabi *et al*. [12]**.** The authors reported that almost all the alkaline pH (pH >7) favored the breeding of mosquitoes in Akure, Nigeria. The pH of Ese-odo is tending toward alkalinity (7.24) this might be as a result of the area being riverine. Ese-odo has the lowest temperature of 25 ºC while Idanre has the highest (27 ºC).

The dissolve oxygen, humidity and temperature of water are the main factors that influence the abundance and distribution of mosquito larva in the aquatic habitats. The temperature range in which mosquito breeding was found in the study area is 25.09-27.22 ºC. This suggests that temperature range of 25.09-27.22 ºC is suitable for mosquito breeding in the study area. This report agrees with the reports given by Adebote *et al*. [13] and Afolabi and Ndams [4]. The authors in their separate studies in Zaria, Nigeria reported that temperature below 24.7 ºC and above 28.3 ºC are fatal to mosquito species. and also that there is inverse relationship between mosquito abundance and temperature as the temperature increases from 24.7 to 29 ºC.

The three ecological zones studied (tropical rainforest, derived savanna and mangrove forest) are favorable for breeding mosquito larvae. In terms of species richness, Ikare-Akoko; a derived savannah with 11 species was the richest ecological zone followed closely by Idanre and Ese-odo with 10 species each. Ondo and Ifon with 9 species each were the least. Of the 12 species of mosquito encountered in the study area only *An. arabiensis* was absent in Idanre. This suggests that the physico-chemical parameters such as dissolved oxygen (2.36ppm/mgl), electrical conductivity (209.33µs), relative humidity (62.67%), temperature (26.25 ºC) and pH 7.07 are most favorable for the breeding of mosquitoes in derived savannah. The absence of *An. arabiensis* in derived savannah (Idanre) and mangrove forest (Ese-odo) might be because of the relative low temperature (25.09-26.25 ºC) in the ecological zone. Contrary, *An. arabiensis* was present in the rainforest (Idanre and Ondo) where temperature is relatively high (26.96-27.22 ºC). The rainforest are usually characterized with high temperature and water. Similarly, all the four species of *Aedes* with the exception of *Ae. palpalis* favorably breed in all the ecological zones. Meanwhile, *Ae. palpalis* larvae were not encountered in rainforest (Idanre and Ondo) but present in derived savannah (Ikare-Akoko) and mangrove forest (Ese-odo). This shows that *Ae. palpalis* and *An. arabiensis* share the same temperature range. *Cx. quinquefasciatus, Cx. andersoni* and *Cx. duttoni* were encountered in all the ecological zones while *Cx. tigripis* were completely absent in Ifon and Ese-Odo, even in areas (Idanre-4, Ondo-6 and Ikare-Akoko-20) where it was found breeding, the abundance was very low. This suggests that the ecological zones in Ondo State do not favor the breeding of this species. Likewise, *Cx. pipiens* was observed to breed better in derived savannah (Ikare-Akoko) and mangrove forest (Ese-odo) than the rainforest (Idanre, Ondo and Ifon). For instance *Cx. pipiens* was completely absent in Ondo and Ifon but breed at a very low abundance (n=8) in Idanre.

5. Conclusions

The results of this study show that the area is rich in mosquitoes, and the abundance of the mosquitoes is attributable to the presence of favorable physico-chemical parameters such as temperature, relative humidity, pH, electrical conductivity and dissolved oxygen. Mosquitoes were observed to breed virtually in all habitats sampled which were ground pools, domestic containers, tanks, tyres, tree holes, gutters and manmade containers. These breeding sites are common in the study area as a result of human activities, poor economic conditions; low literacy levels, poor sanitation level and indiscriminate disposal of discarded household materials which results in abundance of pools, ponds, puddles, water collections in tins, bowls, drums, clay pots, tree holes drums and bucket containers of various sizes used for domestic water collection during raining season. The findings of this study suggest removal of smaller man-made aquatic habitats like abandoned plastics, cans, puddles and tyres could bring about effective larval control of mosquitoes in the study areas. In Idanre, tanks, gutters and puddles should be targeted while controlling mosquito larvae to achieve effective larval control while abandoned plastics, puddles and tyres should be targeted in Ondo. Abandoned plastics should be cleared and recycled, puddles should be drained and gutters should be cleared to control mosquito larva in Ifon. In Ikare-Akoko, tyres, abandoned plastics and gutters should be targeted while puddles, gutters and tyres should be targeted for effective larval control in Ese-Odo.

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